CALIPSO Status

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Mission Overview

- CALIPSO and CloudSat were launched from Vandenberg Air Force Base in California on April 28, 2006
- The sister satellites flew in tight formation in the A-Train constellation to provide first-of-a-kind combined active (lidar & radar) measurements
- CALIPSO's Prime Mission was 3-years; mission operations were extended through Sr Reviews: 2009, 2011, 2013, 2015, 2017, and 2020
- CALIPSO ceased science operations on August 1, 2023 because of depleted fuel reserves

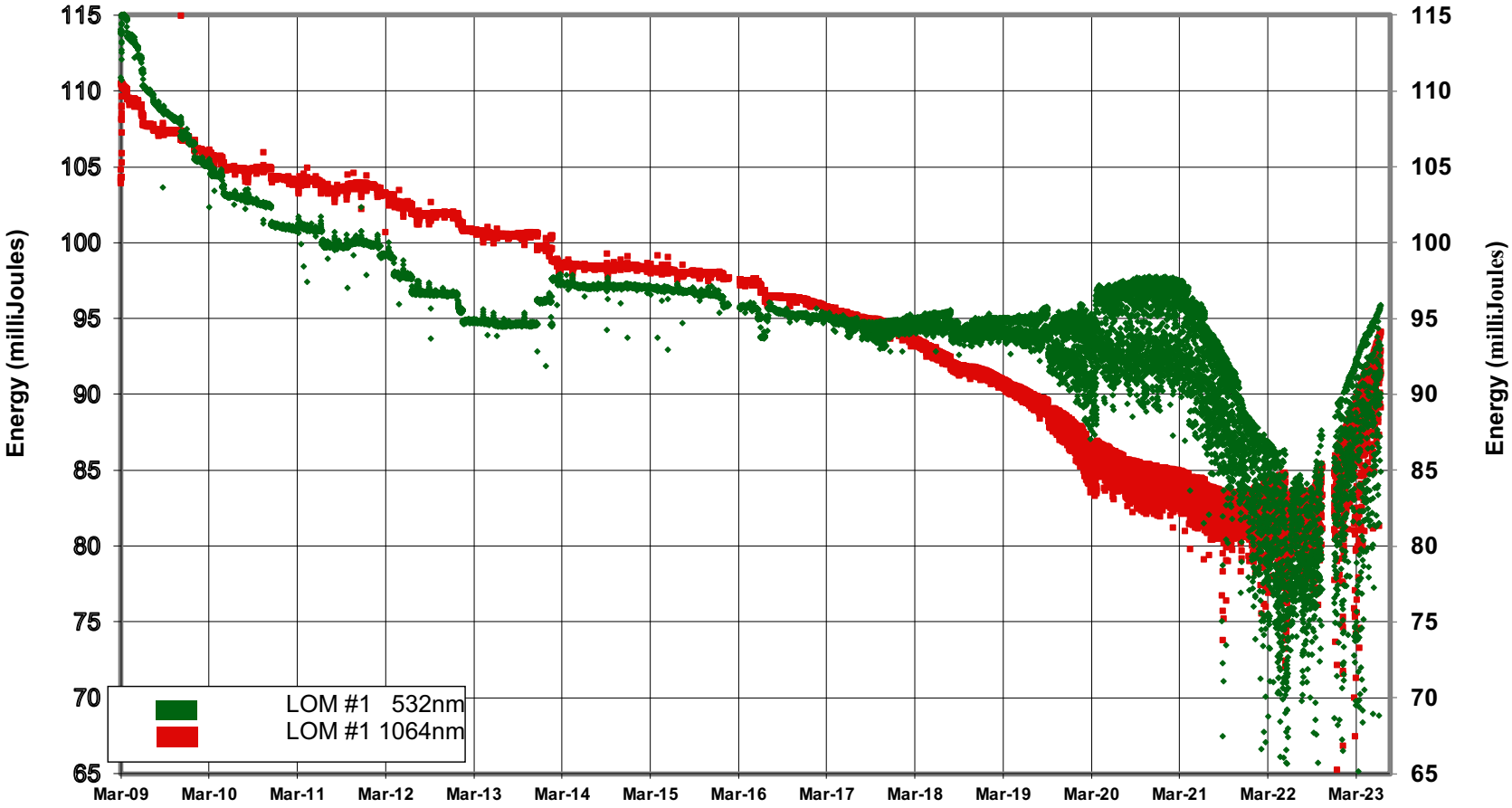
Significant Accomplishments

1. >4200 publications that span a large range of science interest. Findings have been central to IPCC reports and recommendations from 2018 Decadal Survey Recommendations for additional lidar measurements. By many measures – the return value from CALIPSO exceeded the early vision on what could be accomplished and shows that atmospheric lidar is greatly valued and desired.
2. >300 PhD dissertations cited CALIPSO data products in their studies and a core element in their academic education.
3. Formation flying with CloudSat (10-15 s separation) – and the A-Train constellation. Greatly extended utility of CALIPSO measurements and advancement of understanding of the Earth System. Open data access enhanced science exploration.
4. Robustness of CALIPSO payload and spacecraft. + 16 years of on-orbit operations is a major accomplishment (longevity) – especially with CALIOP being a first-of-its-kind on-orbit lidar. FDIR system a great success.
5. Joint NASA payload/CNES spacecraft mission operations team – seamless, collegial, and effective. Unsung heroes that kept the lights on….
6. Pioneered lidar remote sensing algorithms/software system that set the standard for future missions.
7. Effective validation program with airborne/ground based measurement system. LaRC HSRL data (advanced instrument concept) was pivotal to advancing CALIOP data product maturity.
8. New insights and/or discoveries – unranked and only skimming the surface:
   - Unambiguous profile detection of cloud water/ice phase; Hu diagram
   - First comprehensive knowledge of single/multi-level cloud structure over globe – especially at night and in polar regions
   - Location of homogeneous cirrus formation
   - First comprehensive knowledge on occurrence and vertical/geographical distribution of aerosols and their optical properties and typing
   - Initial examination of vertical structure of ocean backscatter from space – opened a new perspective for ocean biology
   - See Science Talk by Dave WInker
8. Benefits to other the interpretation of phenomenon from other observing systems have gained considerable appreciation by the community at large such as for satellite cloud detection, estimates of optical depth, aerosol dust or volcanic plume dispersal to name a few. CALIPSO often considered as ‘truth’.

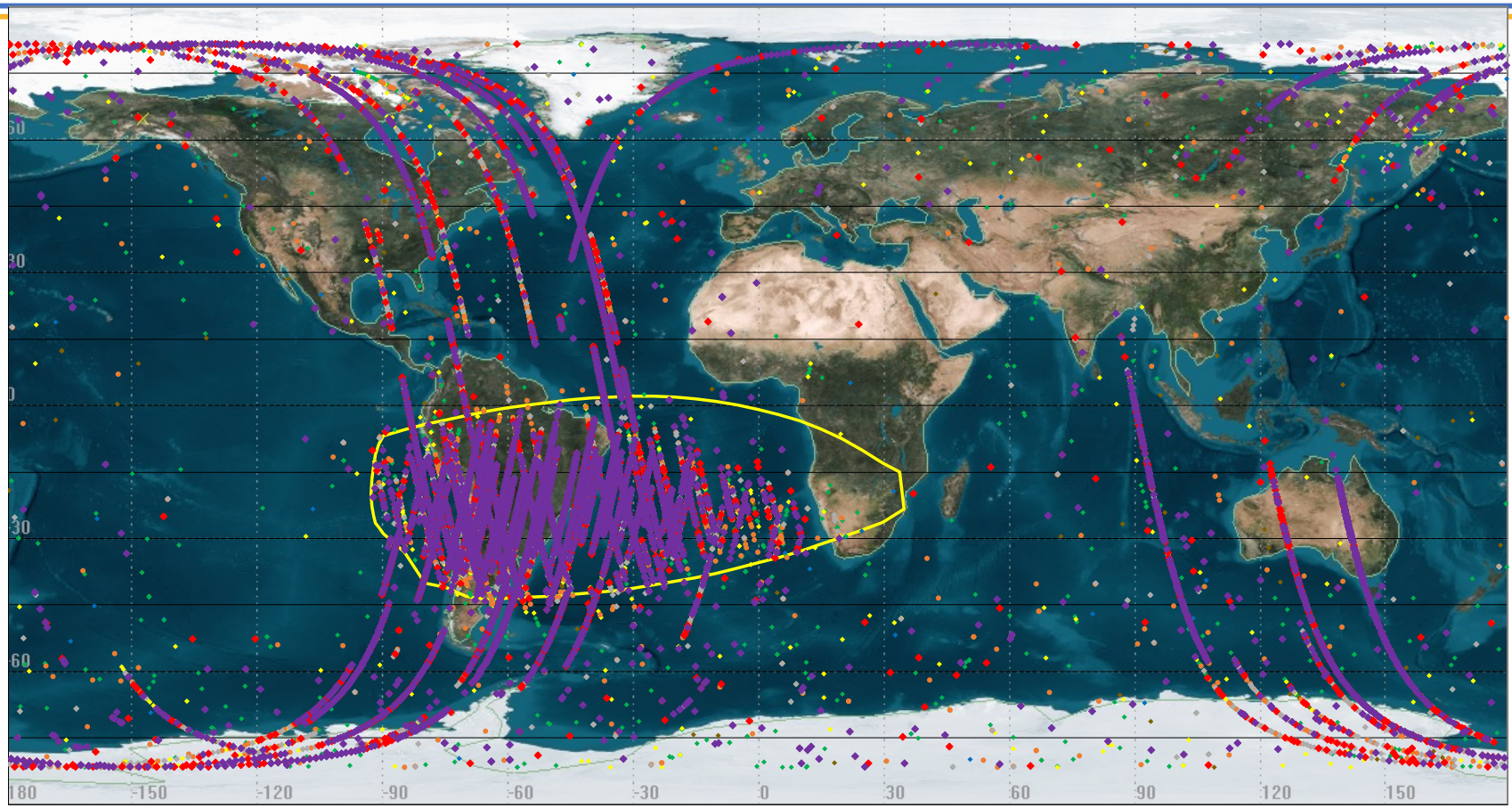
CALIPSO Major Science Contributions

1. **Global 3D characterization of Cloud and Aerosol Observations**: Provided a comprehensive global dataset of cloud and aerosol properties (vertical structure, thickness, and distribution), contributing significantly to our understanding of Earth's atmosphere.
2. **Identification of Aerosol Types**: Contributed to the identification and classification of different aerosol types, such as dust, smoke, pollution, and volcanic ash. This knowledge aids in tracking aerosol transport, their sources and air quality monitoring.
3. **Global phytoplankton blooms during both day and night**: Facilitated the study of global phytoplankton blooms including polar oceans, which are large-scale accumulations of microscopic marine plants. These blooms are important indicators of ocean health, productivity and water quality/turbidity.
4. **Ocean Surface Wind Measurements**: Indirectly provided information about ocean surface winds by measuring the backscattered signals from the ocean surface. This data has been used to study wind patterns, ocean currents, and surface roughness.
5. **Ocean-Atmosphere Interactions:** Supported innovative studies on the interactions between the atmosphere and the ocean, such as the low altitude cloud response to ocean biology changes. These interactions play a crucial role in weather patterns, climate dynamics, and the distribution of marine resources.
6. **Studies of Atmospheric Processes:** Enabled the study of various atmospheric processes, such as the interaction between aerosols and clouds, the influence of aerosols on precipitation, and the role of clouds in regulating Earth's radiation balance.
7. **Longevity and Data Continuity**: Greatly exceeded its initial design life and provided high-quality data. Created a valuable time series of observations, enabling long-term studies and trend analysis, provides rich experiences on future space lidar’s design.
8. **Impact on weather forecasting**: Helped improve weather forecasting models by providing detailed information on cloud vertical structure and aerosol distribution. This has enhanced our ability to predict and understand weather patterns and severe weather events.
9. **Validation of Climate Models**: CALIPSO data has been crucial in validating climate models and improving their accuracy. The observations have helped refine the representation of clouds and aerosols in these models, leading to better climate projections.
10. **Education and Outreach**: Unique educational settings to engage students and the general public in learning about Earth's atmosphere, climate change, and the importance of satellite observations for studying our planet.

Redundant Laser Red and Green Channel Laser Energy

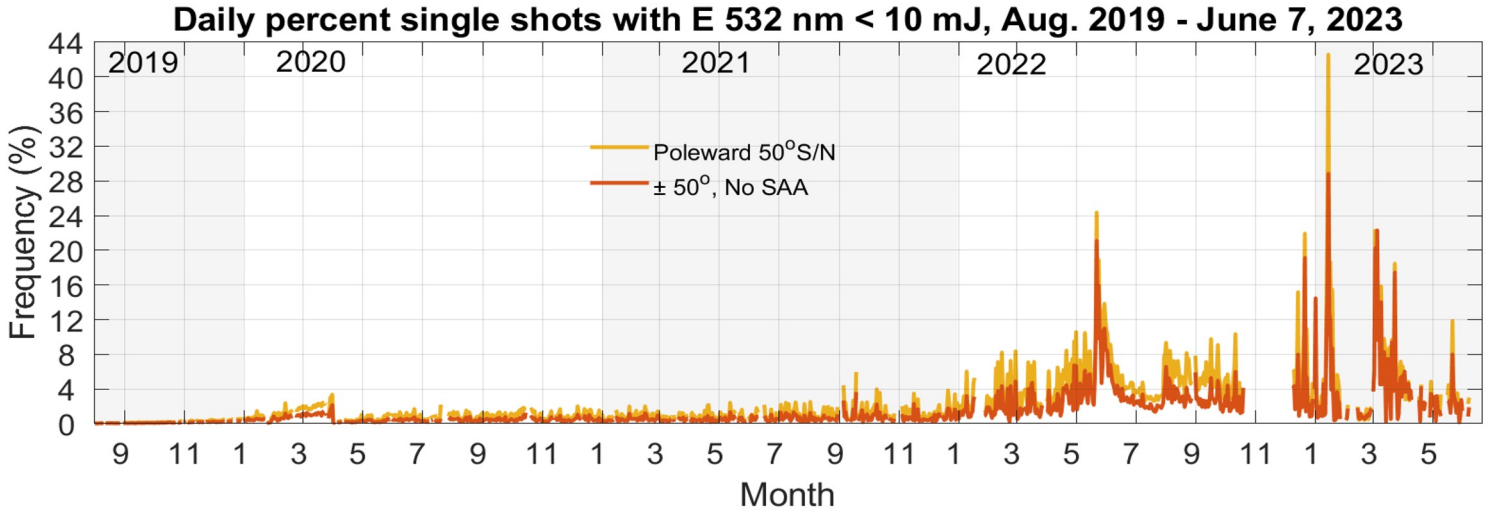


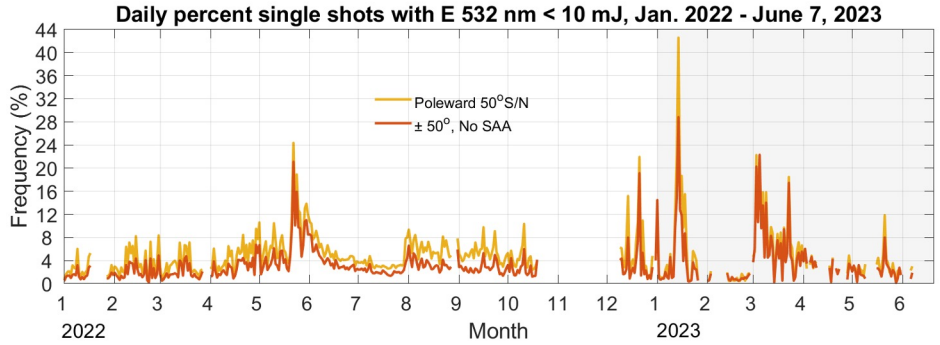
All Laser Energy Drop Locations
June 06 – June 21, 2023



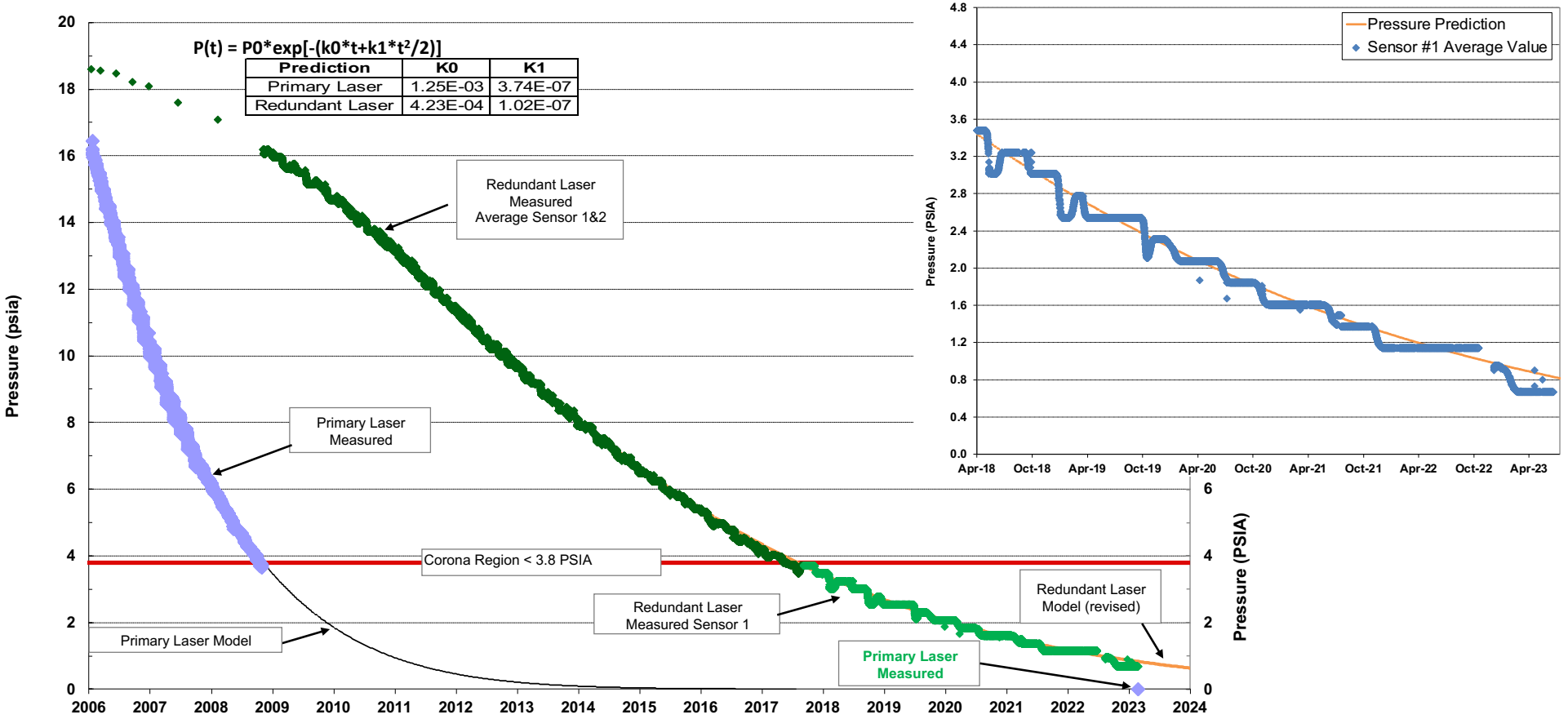
Date Range	Total	E<1 (mJ)	1<E<2 (mJ)	2<E<5 (mJ)	5<E<10 (mJ)	10<E<20 (mJ)	20<E<30 (mJ)	30<E<40 (mJ)	E>40 (mJ)	MAX (mJ)
06/06-06/21/23	15761	328	167	1679	1149	2222	2045	2314	5857	53.8

Low Energy Shots
(single shot data)

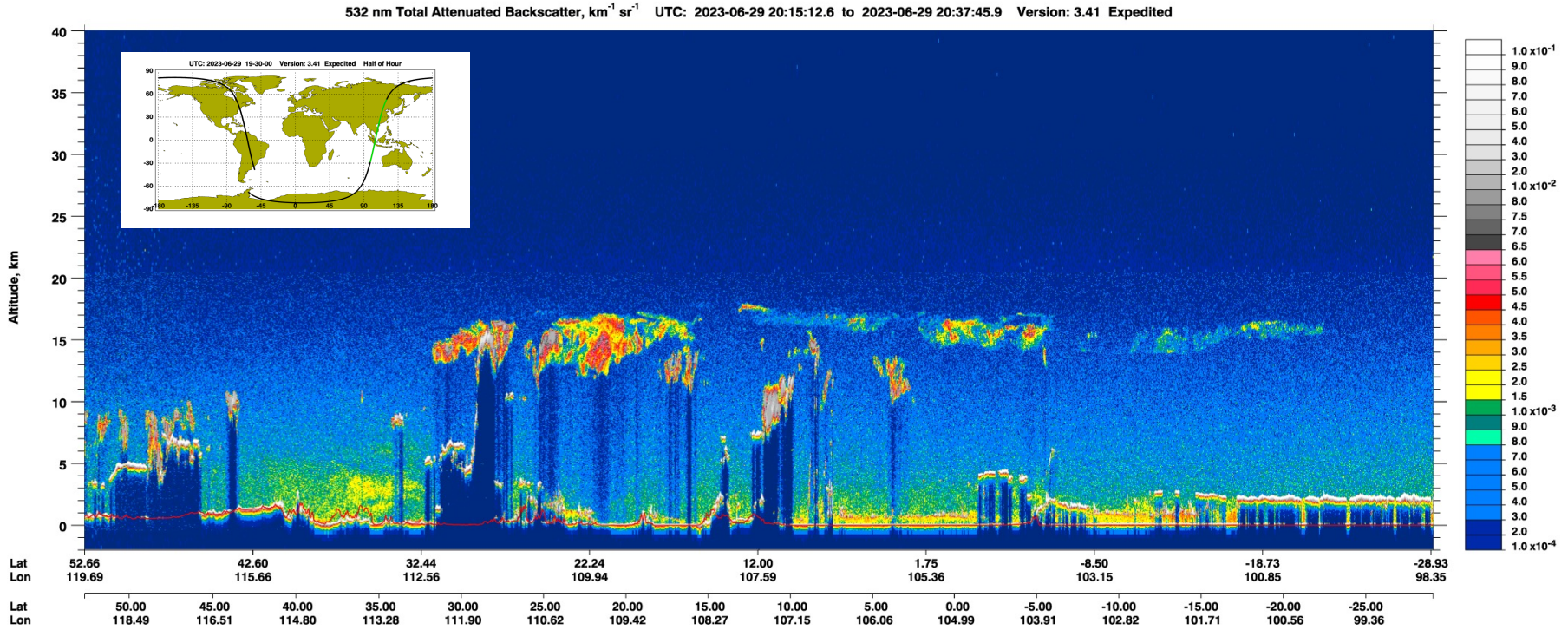




Laser Canister Pressures



CALIPSO Primary Laser
June 29, 2023: 20:37 GMT



Mission Operations Schedule

• End Backup Laser Operations	June 21, 2023
• Restart Primary Laser Operations	June 28, 2023
• Spacecraft Anomaly – suspended payload operations	July 1, 2023
• Terminate Science Operational Phase	August 1, 2023
• LaRC Payload Decommissioning Review	September 6, 2023
• Possible restart of Payload Computer	mid September 2023
• Power-off Payload Computer	
• JSG Mission Decommissioning Review	September 27, 2023
• Platform Assessment Experiments	October-November 2023
• Platform Passivization	January 2024
• Final Report: Mission Operations	February 2024

Letter of Intent to Terminate CALIPSO Mission

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

TO: **Administrator**

FROM: Associate Administrator, Science Mission Directorate

SUBJECT: Notification of Intent to Terminate and Decommission the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) Mission

In compliance with NASA Policy Directive 8010.3B, Notification of Intent to Decommission or Terminate Operating Space Systems and Terminate Missions (Revalidated w/Change 2), this memorandum serves as notification that the Science Mission Directorate (SMD) is preparing to terminate and decommission the joint NASA and Centre National D'Etudes Spatiales (CNES) Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) mission in early Fiscal Year (FY) 2024. The CALIPSO mission's orbit inclination is no longer being maintained due to limited fuel and the spacecraft will drift to a point where the solar arrays are no longer sufficiently illuminated by the sun to generate adequate power to operate both the spacecraft and instrument payload. Currently the CALIPSO spacecraft and instruments are performing well, and the mission is producing valuable measurements for both the research and applications user communities.

CALIPSO was launched on April 28, 2006, on a Delta II launch vehicle from Vandenberg Air Force Base in California and registered as a space object with France as the owner/operator (International Designator 2006-016B, NORAD ID: 29108). The primary mission was completed in 2009 and the mission has continued in an extended operations phase for 14 years, far surpassing its design lifetime of three years.

The CALIPSO spacecraft bus was built in France by Thales-Alenia Space and spacecraft operations are conducted by CNES. NASA Langley Research Center is responsible for the overall mission and payload operations. The payload consists of three co-aligned nadir-viewing instruments: a NASA-provided Cloud-Aerosol Light Detection and Ranging (Lidar) with Orthogonal Polarization (CALIOP) and Wide Field Camera (WFC), and a CNES-provided Imaging Infrared Radiometer (IIR). This combination of an active lidar instrument with passive infrared and visible imagers has enabled global observations of the vertical structure and properties of thin clouds and aerosols. CALIPSO has provided new insight into the role that clouds and atmospheric aerosols play in regulating Earth's weather, climate, and air quality. CALIPSO launched with the NASA CloudSat mission and together they have provided unique three-dimensional perspectives of how clouds and aerosols form, evolve, and affect weather and climate.

For almost 12 years, CALIPSO and CloudSat flew in formation with other satellites in the Afternoon Constellation (also known as the A-Train) to enable an even greater understanding of the Earth's climate system. In 2018, following a reaction-wheel anomaly on CloudSat, both the CALIPSO and CloudSat spacecraft were lowered out of the A-Train orbit into the CALIPSO disposal orbit, in-compliance with the NASA and CNES 25-year orbital debris reentry requirement. The CALIPSO and CloudSat missions resumed formation-flying and have continued science operations in the disposal orbit. Following the CALIPSO orbit-lowering maneuvers, the spacecraft had insufficient fuel reserves to maintain the orbit inclination and has slowly drifted to later equatorial mean local crossing times. As a result of the mean local crossing time drift and a solar panel string failure in the summer of 2022, the CALIPSO orbit will reach a point where the solar arrays can no longer generate enough power to operate both the satellite and the payload. This degradation in power generation is predicted to occur sometime in mid-to-late August 2023.

On April 19, the CALIPSO NASA/CNES Joint Steering Group (JSG) approved the end of science operations to occur on August 1, 2023. Once the science instruments have been powered off, the remaining power margins will allow the CNES team to conduct the spacecraft decommissioning activities through December 2023. An additional JSG is planned for September 27, 2023, to approve the final mission termination and decommissioning activities. In FY2024 the project will transition to Phase F, mission closeout, performing a final reprocessing of the 2006-2023 science data record and archiving the full dataset at the NASA Atmospheric Science Data Center (ASDC) by the end of FY2025.

Nicola J. Fox, Ph.D.

cc:
HQ/Space Operations Mission Directorate/K. Bowersox
HQ/Office of General Counsel/C. Polen
HQ/International and Interagency Relations/K. Feldstein
HQ/Office of the Chief Financial Officer/M. Schaus
HQ/Legislative and Intergovernmental Affairs/A. Brown
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HQ/Office of Communications/M. Etkind
HQ/Office of Protective Services/J. Mahaley
HQ/SMD/W. Peters
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HQ/ESD/D. Considine
HQ/ESD/J. Wicks
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LaRC/ Director/C. Turner
LaRC/ Deputy Director/D. Young
LaRC/Science Directorate/T. Dyal
LaRC/Science Directorate/R. Baize
LaRC/CALIPSO Principal Investigator/ D. Winker
LaRC/CALIPSO Project Scientist/ C. Trepte

Standard Data Product Inventory

Product	Available ASDC	Available ICARE
CALIOP Level 1 (V3)	13 June 2006 – 21 June 2023	13 June 2006 – 21 June 2023
CALIOP Level 1 (V4.51)	13 June 2006 – 20 October 2022	13 June 2006 – 20 October 2022
CALIOP Level 2 (V3)	13 June 2006 – 21 June 2023	13 June 2006 – 21 June 2023
CALIOP Level 2 (V4.51)	13 June 2006 – 31 May 2013	13 June 2006 – 31 October 2011
CALIOP Level 2 (V2) PSC	13 June 2006 – 26 March 2021	13 June 2006 – 26 March 2021
CALIOP Level 2 Blow Snow–Antarctica (V1)	June 2006 – January 2022	June 2006 – January 2022
CALIOP Level 3 Tropo. Aerosol (V4)	June 2006 – December 2021	June 2006 – December 2021
CALIOP Level 3 Cloud (V1) (Ice, Occurrence, and GEWEX)	June 2006 – December 2016	June 2006 – December 2016
CALIOP Level 3 Strat. Aerosol (V1)	June 2006 – December 2021	June 2006 – December 2021
CALIOP Level 1.5 (V1)	13 June 2006 – 19 January 2022	13 June 2006 – 19 January 2022
IIR Level 1 (V1; V2)	13 June 2006 – 30 June 2023	13 June 2006 – 30 June 2023
IIR Level 2 (V3)	13 June 2006 – 21 June 2023	13 June 2006 – 21 June 2023
IIR Level 2 (V4.51)	**TBD**	**TBD**
IIR Level 3 GEWEX (V1)	June 2006 – December 2016	June 2006 – December 2016

Final Processing Strategy

- Summary of approach contained in NASA/CNES CALIPSO End of Mission Science Data Processing Plan (PC-SAT-520)
  - Identified all final data products
  - Mapped out potential updates for each data product, but will defer to schedule if any delays are incurred

- Complete final processing and archival at ASDC and ICARE by August 2025
  - Final review of all algorithm updates to take place in September 2024
  - Processing and archival of the final versions will be phased based on product and scheduled to begin in September 2024, starting with Level 1 data records

Release and Dependency Schedule

Data Product	Target Release Date	Notes/Dependencies
V4.51 IIR L2	Summer 2023	Processing scheduled for Sept. 2023
V1.00 Payload Inst. and Verification Block	Fall 2023	Full mission complete. Need to push to ingest and make orderable on demand.
V1.00 CALIOP Level 0 – Public Format		Algorithm complete. Need to schedule time for processing and ingest.
V2.00 CALIOP L2 Blowing Snow - Antarctica		Algorithm complete. Need to schedule time for processing and ingest.
V1.00 CALIOP L2 Blowing Snow - Greenland		Algorithm complete. Need to schedule time for processing and ingest.
V1.00 CALIOP Level 2 Ocean Product	Winter 2023	Algorithm development on-going, converting research to operational code.
V5.00 CALIOP Level 1	Summer 2025	Start processing/ingest NLT Sept 2024.
V5.00 CALIOP Level 2		Follows V5.00 CALIOP Level 1
V5.00 IIR Level 2		Follows V5.00 CALIOP Level 2
V3.00 CALIOP L2 Blowing Snow - Antarctica		Follows V5.00 CALIOP Level 1 & Level 2
V2.00 CALIOP L2 Blowing Snow - Greenland		Follows V5.00 CALIOP Level 1 & Level 2
V5.00 CALIOP L3 – Tropospheric Aerosol		Follows V5.00 CALIOP Level 2
V2.00 CALIOP L3 – Stratospheric Aerosol		Follows V5.00 CALIOP Level 2
V2.00 CALIOP L3 – Ice Cloud		Follows V5.00 CALIOP Level 2
V2.00 CALIOP L3 – Cloud Occurrence		Follows V5.00 CALIOP Level 2
V2.00 CALIOP L3 – Cloud, GEWEX format		Follows V5.00 CALIOP Level 2
V2.00 IIR Level 3 – GEWEX format		Follows V5.00 CALIOP/IIR Level 2
V1.00 IIR Level 3		Follows V5.00 CALIOP/IIR Level 2

Long Term Data Archive

- Final data products planned to be moved into NASA's Earth Data Cloud for at least 10 years, based on CALIPSO MOU
- CALIPSO science website will be maintained by LaRC Science Directorate
- Science documentation and code will be maintained on CALIPSO SharePoint repository (discussed later)
  - ASDC will have full access to this repository to facilitate detailed preservation as outlined in NASA Earth Science Data Preservation Content Specification 423-SPEC-001 (AD12)

Payload Major Events

April 28, 2006 (Launch) - September 2018
- A-Train Science Operations

July 2006
- First of 119 High Power Holds (inhibits laser for overflights, HST etc)

October 2006
- Spurious Interrupt Mask (X-Band Transmits

December 2006
- First Solar Flare (payload powered down)

November 2007
- Off-Nadir angle changed to 3.0 degrees

March 2008
- Satellite Safe Hold Mode (Reaction Wheel SEU)

June 2008 – September 2008
- Laser Rep Rate Error; Flight Software update developed and implemented

February/March 2009
- Switch primary to redundant laser science operations

November 2010
- Computer Boot Code updated

February 2011
- Risk Mitigation Maneuver (RMM)

January 2014
- First night orbit Off-Nadir experiment (20 degrees)

January - March 2016
- Platform GPS Fix (Week number rollover)

October 2016
- Payload power cycled after 193,242 memory scrub errors observed

February – June 2017
- Extended Off-Nadir experiments (1,1.5,2,14 degrees)

September 2018
- A-Train Exit
- Satellite lowered to its disposal orbit

April 2020
- Wide Field Camera (WFC) stopped communicating (turned OFF)

September – October 2022
- Payload placed in low consumption mode, due to decreased power.

July 2016 – June 2023
- Low Energy Laser shots due to decreased cannister pressure
- Evolved from a few millijoules to bursts with little output Energy

June 2023
- Primary laser re-activation

July 2023
- Satellite Safe Hold Mode (Data Handler Unit, TBD)

Mission Partners

NASA Langley Research Center
- Mission and Science Leadership
- Payload Operations
- Science Data Processing, Distribution and Archive

CNES Toulouse Space Center
- Imaging Infrared Radiometer (IIR)
- Proteus Spacecraft and Flight Operations

Ball Aerospace
- Lidar (CALIOP), Wide field of view Camera (WFC)
- Payload Computer, X-band Transmitter and Downlink Services

FiberTek
- Primary and Redundant Lasers

IPSL
- Science leadership, French Data Archive

Hampton University
- Science (prime mission)